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NAME	COUNTRY
NEWALL ELECTRONICS LTD	N/A

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ABSTRACT:

A device which uses inertial navigation techniques to measure dimensions of an object comprises a probe body having a barrel 1 and, optionally, a pistol-like grip 2. A probe tip 3 extends from the body, its free end 5 being aligned with the longitudinal axis 6 of the body. Inside the body are six accelerometers, 7 to 12, which are respectively aligned parallel to three orthogonal axes x,y,z, the x-axis being coincident with the body's longitudinal axis 6. Upon movement of the free end 5 of the probe tip 3 from a predetermined datum, data from the accelerometers, 7 to 12, representing the acceleration of the free end of the probe tip in six degrees of freedom, after suitable processing, is integrated twice by an electronic calculating assembly

14 to provide an output indicative of the instantaneous position of the probe tip free end 5 relative to said datum, which may be visually displayed by a device 15. <IMAGE>

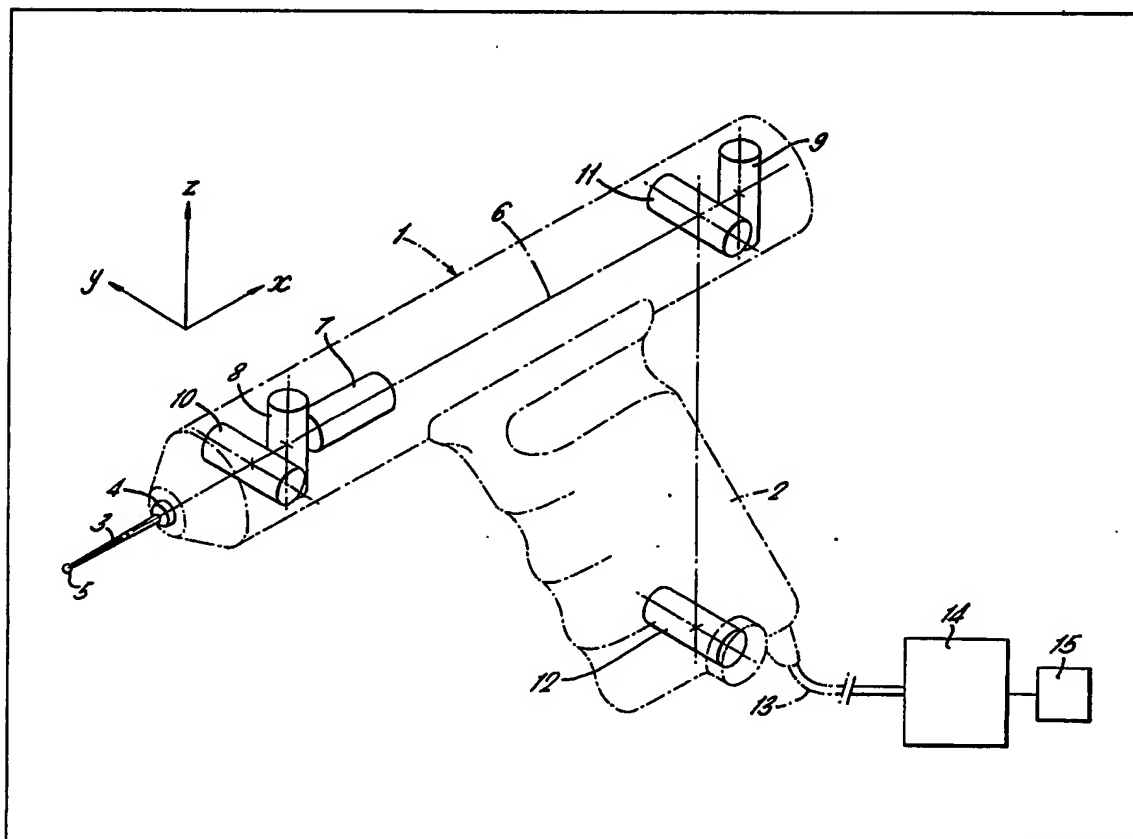
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(71) Applicants
Newall Electronics
Limited, 20 Ivatt Way,
Westwood, Peterborough
(72) Inventor
Kelvin Roger Davis
(74) Agents
Boulton, Wade & Tennant

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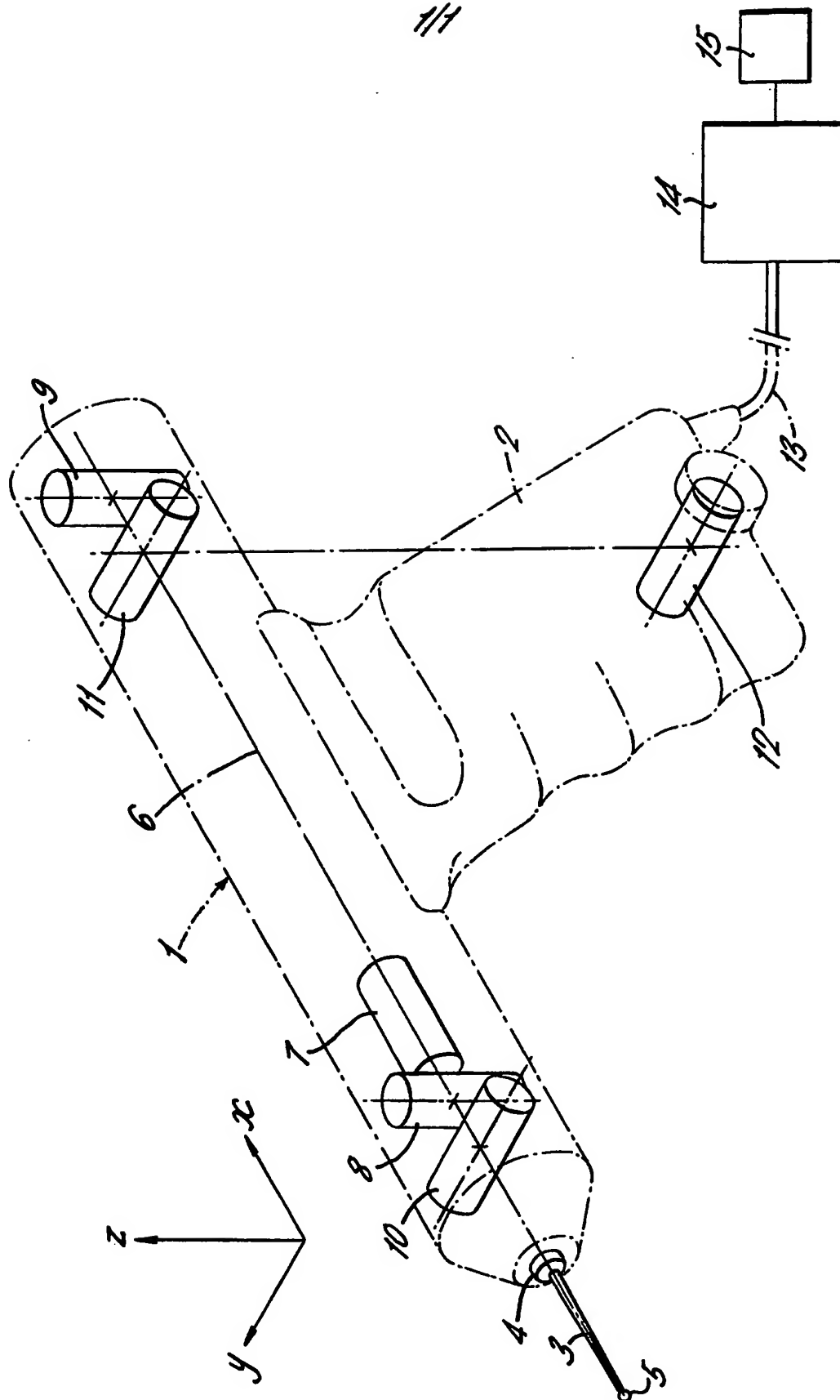
(57) A device which uses inertial navigation techniques to measure dimensions of an object comprises a probe body having a barrel 1 and, optionally, a pistol-like grip 2. A probe tip 3 extends from the body, its free end 5 being aligned with the longitudinal axis 6 of the body. Inside the body are six accelerometers, 7 to 12, which are respectively aligned parallel to three orthogonal axes x , y , z , the x -axis being coincident with the body's longitudinal

axis 6. Upon movement of the free end 5 of the probe tip 3 from a predetermined datum, data from the accelerometers, 7 to 12, representing the acceleration of the free end of the probe tip in six degrees of freedom, after suitable processing, is integrated twice by an electronic calculating assembly 14 to provide an output indicative of the instantaneous position of the probe tip free end 5 relative to said datum, which may be visually displayed by a device 15.



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SPECIFICATION

Dimension measuring device

5 This invention relates to a device for measuring dimensions of, for example an object using inertial navigation techniques, i.e. measuring the physical dimensions of the object by determining the changes in the position of the end of a probe tip held
10 in contact with different parts of the object. The device is suitable for accurate measurements in three dimensions i.e. length, width and height.

Existing position or dimension measuring devices typically have the form of a travelling gantry
15 mounted on a reference table, (i.e. a table, typically of steel or granite, having a surface which is flat to a high degree of accuracy). The position of the gantry along its axis of movement is determined, using for example, optical measurement techniques. The gantry carries a probe which is free to move both vertically and laterally and similar means of determining the position of the probe. As may be imagined, such a structure is large and unwieldy, and has a limited working space.

25 According to the present invention, there is provided a dimension measuring device comprising a portable rigid probe body; a probe tip which protrudes from the body; sensor means for sensing acceleration of the end of the probe tip in six degrees
30 of freedom; and integrating means for receiving and integrating the acceleration data from said sensor means to provide an output indicative of the instantaneous position of the free end of said probe tip relative to a predetermined datum.

35 By measuring the acceleration of the free end of the probe tip in six degrees of freedom (i.e. three translational and three rotational degrees of freedom) and performing a mathematical integration with respect to time twice on the acceleration data
40 obtained, the instantaneous position of the free end of the probe tip can be determined with respect to the predetermined datum on which the data and hence the integration procedure is based. Thus if the free end of the probe tip is held in contact with two
45 successive points on an object to be measured, a double integration of the acceleration data deriving from its movement between the successive points will enable the ready determination of the required dimension, irrespective of the path actually traced by
50 the end of the probe tip.

The body of the device is small enough to be portable, and in a preferred embodiment is pistol-like, the pistol-like grip serving the dual function of a mounting for one of the six accelerometers used in
55 the acceleration measurement, and as a housing for electronic circuitry used in processing the accelerometer output for transmission to the integrating means which is preferably external to the body, whether *via* a direct cable link or *via* a radio,
60 optical acoustic or other link.

Reference is now made to the accompanying drawing of which the sole Figure illustrates, by way

of example, one embodiment of the invention.

The portable probe body of a dimension measuring device according to the illustrated, preferred embodiment of the invention comprises a hollow barrel 1 from which extends laterally a manual grip 2, giving the body a pistol-like appearance. A probe tip 3 having a stem of high rigidity, e.g. tool steel, and a free end 5 in the form of a wear-resistant spherical ball, e.g. of tungsten carbide, is mounted in a collet fitting 4 in one end of the barrel 1, the free end 5 of the probe tip 3 being shaped to contact an object to be measured. The mounting of the probe tip 3 is such that the end 5 of the probe tip 5 lies on the longitudinal axis 6 of the barrel 1.

Six linear accelerometers 7 to 12 are rigidly mounted within the probe body, being aligned respectively parallel to three orthogonal axes *x*, *y* and *z*, of which the directions are diagrammatically illustrated in the drawing. The *x*-axis is in fact taken as being coincident with the longitudinal axis 6 of the barrel 1, the origin of the three axes being the centre of the end 5 of the probe tip 5. Of the six
85 accelerometers, the accelerometer 7 is aligned along the *x*-axis (i.e. the longitudinal axis 6 of the barrel), and the accelerometers 8 and 9 are both aligned parallel to the *z*-axis, the accelerometers 8, 9 being located in the barrel 1, are at each end thereof. The
90 remaining three accelerometers 10, 11 and 12 are all aligned parallel to the *y*-axis, the accelerometer 12 being located in the end of the pistol-like grip 2 furthest from the barrel so that it is spaced from the *x*-axis, and the other two of these three accelerometers, namely accelerometers 10 and 11 are located
95 within the barrel 1, one at each end thereof. Thus the arrangement is that three accelerometers 7, 8 and 10 respectively aligned parallel to the three orthogonal axes *x*, *y* and *z*, are located at the end of the barrel 1 nearest the probe tip 3, two accelerometers 9 and 11
100 respectively aligned parallel to the *z*-axis and *y*-axis are located at the opposite end of the barrel 1, whilst the accelerometer 12 is located in the pistol-like grip 2. As illustrated, in this embodiment, the
105 accelerometers 11 and 12 are spaced apart in a direction parallel to the *z*-axis.

The data which issues continuously from the accelerometers 7 to 12 is supplied *via* a link 13, here shown as a direct cable link, to a programmable electronic calculating assembly 14 which may be either an analogue or digital computer and which is programmed to perform mathematical operations thereon to derive an indication of the instantaneous position of the end 5 of the probe tip relative to a pre-set datum as described below. Conveniently, a visual display device 15 is connected to the output of the calculating assembly to display the positional data. The body, namely the grip 2 and the otherwise unused portions of the barrel 1, may be used to house electronic circuitry for processing the output
120 of each accelerometer to translate it from acceptable to the calculating assembly 14. For example, in place of the direct cable link 13 shown, the data may be transmitted to the calculating assembly 14 *via* a

The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.

radio, optical, acoustic or other suitable link, which increases the utility and convenience of the measuring device.

- 5 It should of course be noted that providing sufficient space is available inside the body, the electronic calculating assembly and/or the display device may be incorporated in the body, making the measuring device self contained.

The calculating assembly is programmed to
10 resolve the data from the accelerometers 7 to 12 about the end 5 of the probe tip, and to combine the data from one or more of the accelerometers in prescribed patterns to determine the acceleration of the end 5 of probe tip in the respective six degrees of
15 freedom. For the illustrated arrangement of accelerometers, the data is combined as follows.;

(a) For translational motion of the end 5 of the probe tip along the x-axis data is collected from accelerometer 7, for motion along the y-axis, data is
20 collected from accelerometers 10, 11 and 12, and for motion along the z-axis data is collected from accelerometers 8 and 9.

(b) The data from accelerometers 10, 11 and 12 provides the acceleration data for rolling motion of the probe tip 5 (i.e. rotation about the x-axis), the
25 data from accelerometers 8 and 9 provides the acceleration data for pitching (i.e. rotation about the y-axis), and the data from acceleration 10, 11 and 12 provides the acceleration data for yawing motion
30 (i.e. rotation about the z-axis).

The calculating assembly is arranged to add or subtract the relevant data to determine the acceleration data for each degree of freedom as required. Two mathematical integration operations with
35 respect to time are then performed on the acceleration data by the calculating assembly to obtain the positional data for the end 5 of the probe tip. The datum for this positional data can be permanently programmed into the calculation assembly or alternatively, means may be provided for instructing the
40 calculating assembly to recognise one or more probe positions as constituting datum axes or planes.

The accuracy of the measurements made depends
45 of course on the accuracy with which the accelerometers 7 to 12 are mounted in the body with respect to each other, to the axes x, y and z and to the probe tip and the accuracy with which they can supply data as the body moves. Preferably, the
50 alignment of each accelerometer should be accurate to within 1.0 arc seconds and 0.0001 inches. In order that temperature fluctuations do not degrade the accuracy of the measurements to an unacceptable degree by altering the relative spacing of the
55 accelerometers, the body may be made of a material having a low temperature coefficient of expansion, for example "INVAR" (Registered Trade Mark).

Alternatively the electronic calculating assembly or
60 arranged to provide adequate temperature compensation.

It should be noted that up to three of the linear accelerometers illustrated in the drawing may be replaced by a respective angular accelerometer
65 appropriately aligned with a respective one of the

three orthogonal axes x, y and z. If the accelerometer 12 used to measure rolling motion is replaced by an angular accelerometer it no longer needs to be spaced from x-axis but can be located in the barrel 1 and aligned with the x-axis itself; in this case, the pistol-like grip may be omitted, leaving only the barrel 1 containing all six accelerometers, or alternatively it could be retained for use in housing the electronic circuitry. Thus in the extreme case, the
70 arrangement might be three accelerometers, e.g. accelerometers 7, 8, and 10, at one end of the barrel 1 used to determine translational motion and three angular accelerometers at the other end of the barrel used to determine rolling, pitching or yawing respectively.
75

Preferably, the probe tip 3 is detachable from the body so that replacement probe tips of different sizes and shapes may be used to suit the shape of an object to be measured. In each case, in order that the
85 acceleration data from the accelerometers can be accurately resolved about the centre of the probe tip, the length of the probe tip 3 and its free end 5 to its connection to the body must be programmed into the electronic calculating assembly, and the probe
90 tip fitted to the body with datum faces on the probe tip seating and on the probe body properly engaged.

The manner in which the device according to the invention and the use to which the output of the calculating assembly is put are, of course, not critical. For example, it would not affect the measurement of the dimension of an object between two points if the end of the probe tip were to be moved from one point to the other in contact with the body or whether it is merely brought into contact with the
100 object at first one point and then the other provided that the calculating assembly is programmed by suitable means as to the points between which measurement is required and the nature of the measurement required e.g. straight line measurement. Similarly, the calculating assembly may be
105 programmed to manipulate the positional data in a variety of ways. The simplest arrangement is the continuous display on the visual display device of the position of the end of the probe tip in rectangular or other coordinates relative to the chosen datum. Alternatively, the calculating assembly may be programmed with the required dimension of an object e.g. a machined workpiece, and only cause the display of deviations of the actual shape of the object from the programmed required shape.
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To prevent possible over-speeding of the calculating assembly, the probe body may be adapted to be detachably supported on an articulated arm structure which incorporates some form of motion damping.
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CLAIMS

1. A dimension measuring device comprising a portable rigid probe body;
a probe tip which protrudes from the body;
125 sensor means for sensing acceleration of the end of the probe tip in six degrees of freedom; and integrating means for receiving and integrating the acceleration data from said sensor means to provide an output indicative of the instantaneous position of the free end of said probe tip relative to a predetermined
130

datum.

2. A dimension measuring device as claimed in claim 1, in which said sensor means comprises six accelerometers rigidly mounted within said body and aligned parallel to three orthogonal axes, there being means for combining the data from one or more than one particular accelerometer to produce the acceleration data deriving from the movement of the end of the probe tip in each respective degree of freedom.

3. A dimension measuring device as claimed in claim 2, in which said six accelerometers include at least one angular accelerometer.

4. A dimension measuring device as claimed in claim 3, in which said body comprises an elongate member which is longitudinally aligned with a first one of said three orthogonal axes, said probe tip extending from one end of said body so that the free end of the probe tip lies on said first orthogonal axis.

5. A dimension measuring device as claimed in claim 2, in which said sensor means comprises six identical linear accelerometers.

6. A dimension measuring device as claimed in claim 5, in which said body comprises an elongate member which is longitudinally aligned with a first one of said three orthogonal axes, said probe tip extending from one end of said body so that the free end of the probe tip lies on said first orthogonal axis.

7. A dimension measuring device as claimed in claim 6, in which one of said accelerometers is aligned with said first orthogonal axis, a pair of said accelerometers is aligned parallel to a second one of said three orthogonal axes, and the remaining three accelerometers are aligned parallel to the third orthogonal axis.

8. A dimension measuring device as claimed in claim 7, in which said body is pistol-shaped, having a pistol-like grip which extends laterally from the elongate member, the accelerometers being arranged within said body so that said one accelerometer, said pair of accelerometers and two of said remaining three accelerometers are located in the elongate member, and the third of said remaining three accelerometers is located in the grip and is spaced from the first orthogonal axis.

9. A dimension measuring device as claimed in claim 8, in which the two accelerometers which are aligned parallel to said second orthogonal axis and located within the elongate member are spaced apart along the first orthogonal axis, and in which the two accelerometers within the elongate member which are aligned parallel to the third orthogonal axis are also spaced apart along the first orthogonal axis.

10. A dimension measuring device as claimed in any of claims 1 to 9, in which the probe body is made of a material having a low temperature coefficient of expansion.

11. A dimension measuring device as claimed in any of claims 1 to 10, in which said probe tip is detachable from the body.

12. A dimension measuring device as claimed in any of claims 1 to 11, in which the body contains electronic circuitry for processing said data from said accelerometers into signals suitable for recep-

tion by said integrating means and for transmitting said signals to said integrating means for subsequent integration.

13. A dimension measuring device as claimed in any of claims 1 to 12, including a visual display device operatively connected to the output of said integrating means and arranged to provide a visual display of that output.

14. A dimension measuring device as claimed in any of claims 1 to 12, in which the body is adapted for mounting on an articulated arm structure.

15. A dimension measuring device substantially as hereinbefore described and illustrated in the accompanying drawing.

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